भारतीय मानक
Indian Standard

IS 6531 : 2021

नहरों के मुख्य नियामक — डिजाइन की कसौटी

(दूसरा पुनरीक्षण)

Canal Head Regulators — Criteria for Design

(Second Revision)

ICS 93.160

भारतीय मानक ब्यूरो
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FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards after the draft finalized by the Canals and Cross Drainage Works, had been approved by the Water Resources Division Council.

Regulators provided at the head of canal off taking from a river is termed as canal head regulator. It serves the purpose to regulate the supplies entering the canal and to control the silt entry into the Canal.

This Standard was published in 1972 and the first revision was adopted in 1994. The important modifications made in the first revision were:

a) Layout for curved channel head regulator in case of head works for spate irrigation system was added;

b) Determination of value of C was modified; and

c) Design criteria for curved channel sediment excluder for spate irrigation head works were included.

The second revision of this standard has been made in view of the experience gained during the course of past years with use of this standard. In the present revision, the important modifications are as given below:

a) The formula for discharge in case of partly opened gates has been revised as:

$$Q = CL_e\left[H_1^{3/2} - H_2^{3/2}\right].$$

b) Figure 5 H_e/L is given for different curves. value of 'L' can be determined by model test analysis.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CANAL HEAD REGULATORS — CRITERIA FOR DESIGN

(Second Revision)

1 SCOPE

This Indian Standards covers the criteria for the hydraulic design of canal head regulators.

2 REFERENCES

The Indian Standards listed contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS No.	*Title*
4997 : 1968	Criteria for design of hydraulic jump type stilling basins with horizontal and sloping apron
10430 : 2000	Criteria for design of lined canals and guidance for selection type of lining (*first revision*)

3 LOCATIONS AND LAYOUT

3.1 Location

The location of canal head regulator is interlinked with the location of diversion work. The head regulator should be located as close to the diversion structure as possible and preferably at the end of the outer curve (convex bend), if available, to minimize the sediment entry into the off taking canal (*see* Fig. 1A).

3.2 Layout

The canal head regulator should be properly aligned so as to reduce silt entry into the canal to a minimum and avoid backflow and formation of stagnant zones in the pocket. To achieve this, the axis of canal head regulator may be located at an angle of 90° to 110° (*see* Fig. 1B) with respect to the axis of the diversion work. This may, however, be confirmed from model studies, if necessary. A typical layout of the canal head regulator is given in Fig. 2.

Layout of canal head regulator in case of head works with sediment excluder is given in Fig. 3.

4 HYDRAULIC DESIGN

4.1 General

The hydraulic design of canal head regulator consists of the following:

a) Fixation of pond level (including losses through structures);
b) Fixation of sill level, width of sill and shape of sill;
c) Fixation of waterway, number and width of spans and height of gate openings, requirements of breast wall etc;
d) Shape of approaches and other component parts;
e) Safety of structure from surface flow considerations;
f) Safety of structure from sub-surface flow consideration; and
g) Energy dissipation arrangements, terminal structures.

4.2 Pond Level

Pond level, in the under-sluice pocket, upstream of the canal head regulator should generally be obtained by adding the working head to the designed full supply level in the canal. The working head should include the head required for passing the designed discharge into the canal and the head losses in the regulator. If under certain situations there is a limitation of pond level, the full supply level should be fixed by subtracting the working head from the pond level. In regions of high altitude where there is a possibility of ice formation, a cover of ice of about 0.5 m may be added to the working head.

4.3 Sill Level

Sill level should be fixed by subtracting from pond level the head over the sill required to pass the full supply discharge in the canal at a specified pond level. To obtain control on entry of silt into the canal it is desirable that the sill of head regulator should be kept as much higher than the sill of under sluices, as possible, commensurate with the economic waterway and the driving head available. If a silt-excluder is provided, the sill level of head regulator should be determined in conjunction with the design requirements of silt-excluder.

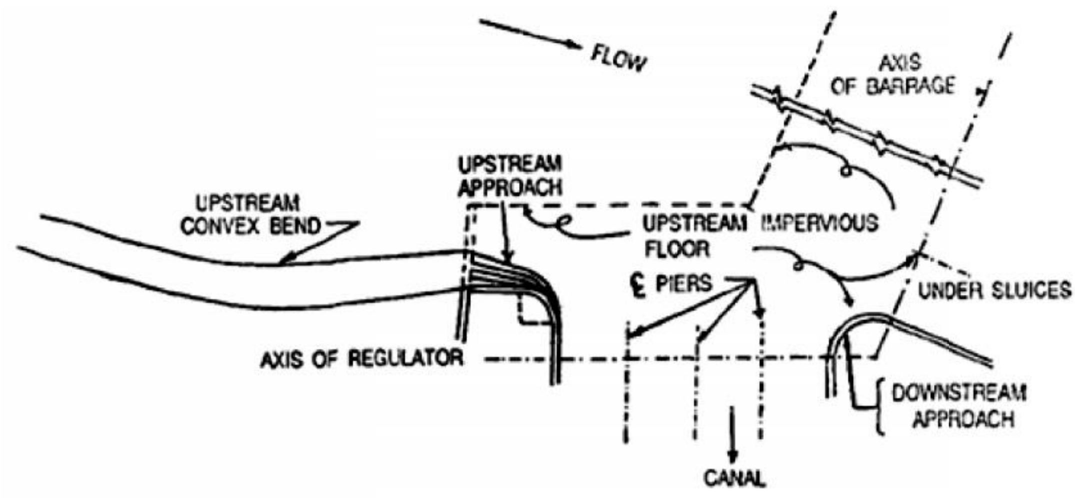


FIG. 1A CANAL HEAD REGULATOR DOWNSTREAM A CONVEX BEND

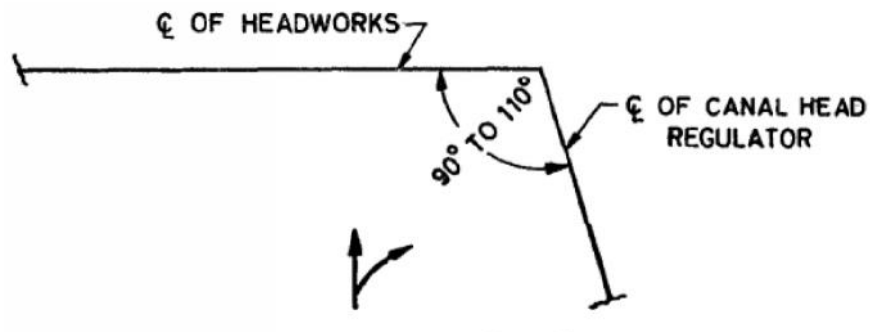


FIG. 1B ALIGNMENT OF HEAD REGULATOR

FIG. 1 HEAD REGULATOR TYPICAL ALIGNMENT

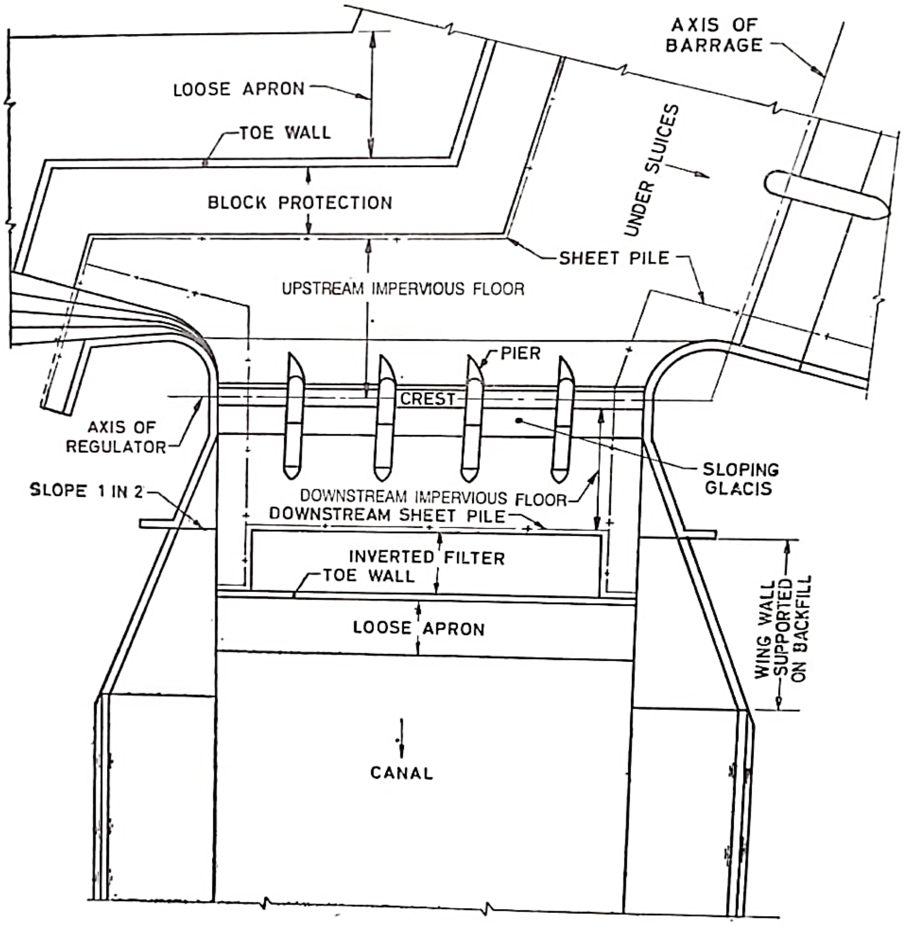


FIG. 2A TYPICAL PLAN OF HEAD REGULATOR

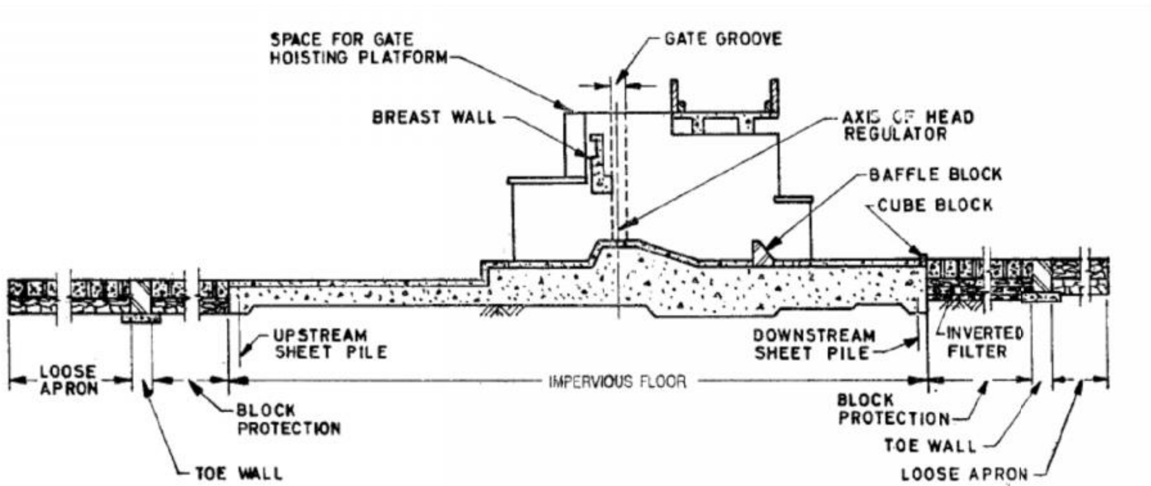


FIG. 2B TYPICAL SECTION OF HEAD REGULATORS

FIG. 2 LAYOUT OF CANEL HEAD REGULATOR

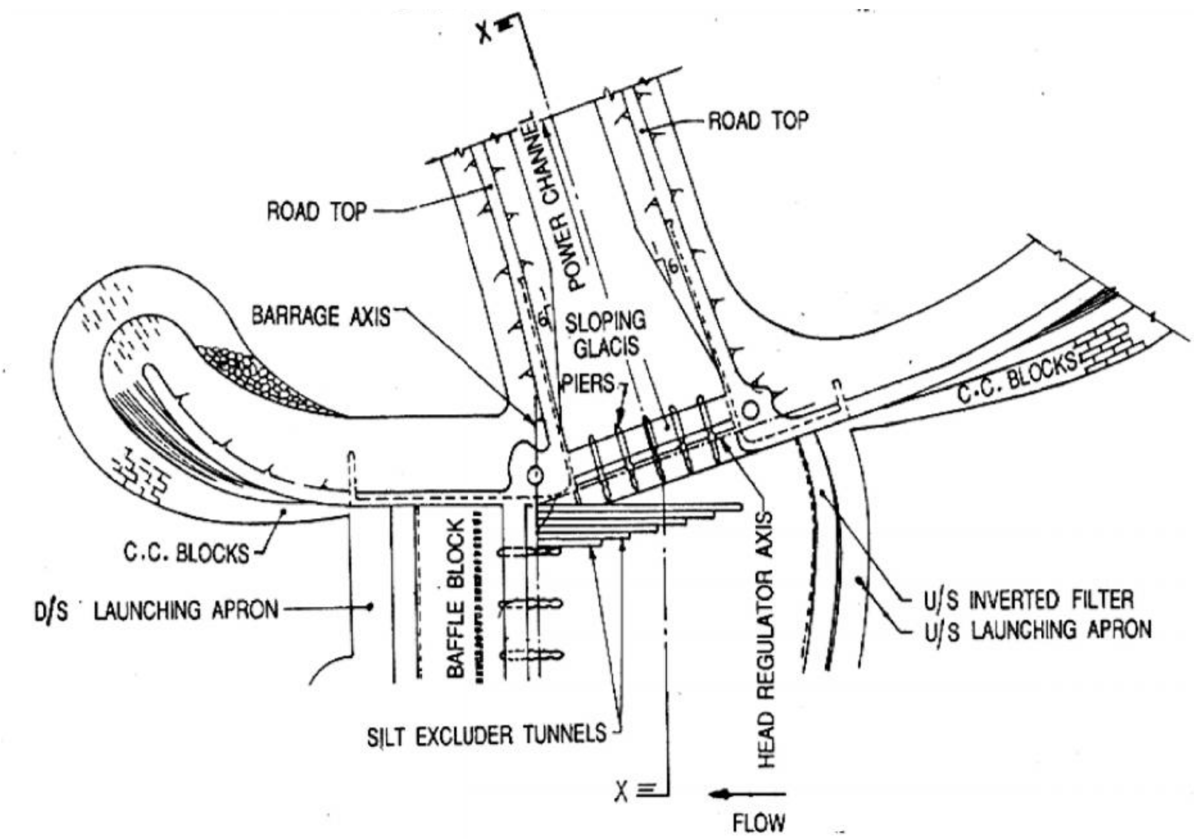


FIG. 3A TYPICAL PLAN OF HEAD REGULATORS WITH SEDIMENT EXCLUDER

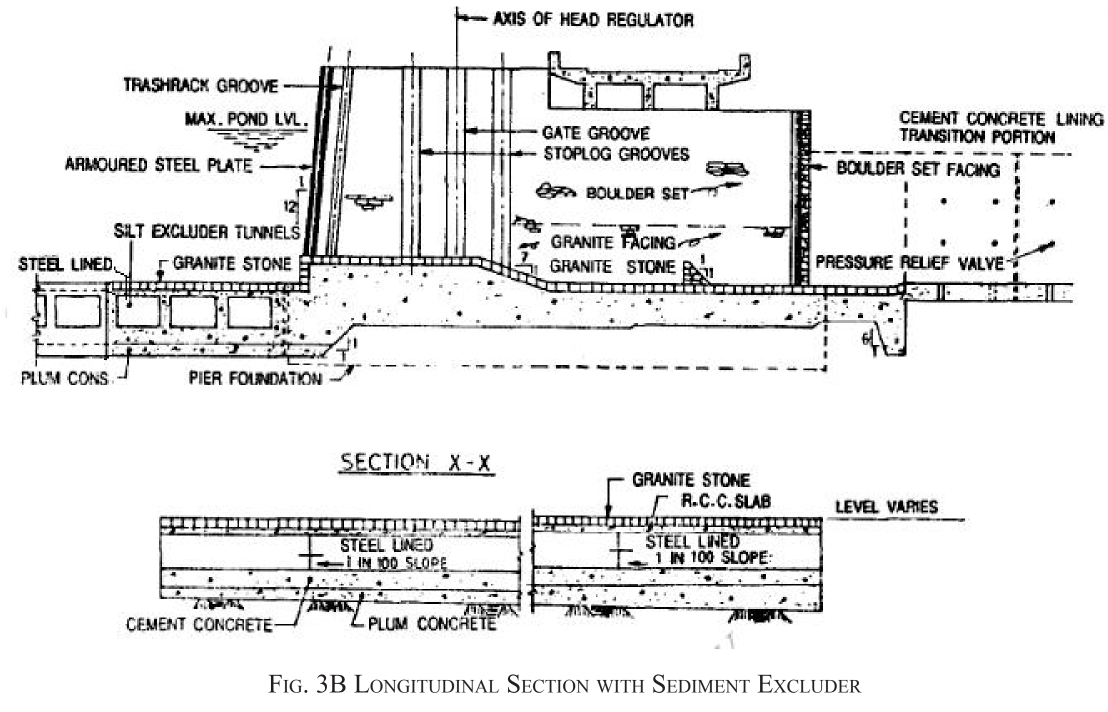


FIG. 3B LONGITUDINAL SECTION WITH SEDIMENT EXCLUDER

FIG. 3 LAYOUT OF CANAL HEAD REGULATOR WITH SEDIMENT EXCLUDER

4.3.1 The required head over the sill H, for passing a discharge Q, with the effective waterway L_e, should be worked from the following formula:

$$Q = C.L_e.H_e^{3/2}$$

where

Q = discharge in m³/s;
C = coefficient of discharge;
L_e = effective waterway in m; and
H_e = required head over the crest for passing a discharge Q, in m.

4.3.1.1 In the formula given in **4.3.1** the exact value of C depends on many factors, such as head over the sill, shape and width of the sill (W), upstream slope (Z_1) and downward slope (Z_2) of the sill, height over the upstream floor (P) and roughness of its surface. Some values of C/C_{dt} for varied H_e/P and H_e/W for un gated flow and for $Z_1 = 0$, $Z_2 = 2$ and $Z_2 = 3$ are shown in Fig. 4. C_{dt} is the theoretical value of coefficient of discharge generally taken as 1.705. The discharge reduction factor for varied submergence ratios H_d/H_e should be obtained from Fig. 5 (where H_d is depth of tail water level above the crest). The values of C should be determined by the model studies where values based on prototype observations on similar structures are not available.

When the outflow is controlled by partly open gates, conditions similar to sluice flow develops. The required head in this case may be computed by the following equation:

$$Q = C\,L_e\left[H_1^{3/2} - H_2^{3/2}\right]$$

where

Q = discharge, in m³/s;
C = coefficient of discharge;
L_e = effective waterway, in m; and
H_1 and H_2 = total heads to the bottom and top of the orifice, in m.

4.3.2 *Width of Sill*

Width of sill should be kept according to the requirements of the gates, trash and stop logs subject to a minimum of 2/3 H_e.

4.3.3 *Shape of Sill*

The edges of sill should be rounded off with a radius equal to H_e. The upstream face should generally be kept vertical and the downstream sloped at 2 : 1 or flatter.

4.4 Having decided upon the effective waterway, the total water way between the abutments including piers should be worked out from the following formula:

$$L_t = L_e + 2\,(N K_p + K_a)\,H_e + W$$

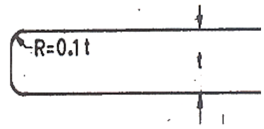
where

L_t = total waterways, in m;
L_e = effective waterways, in m;
N = number of piers;
K_p = pier contraction coefficient (*see* **4.4.1**);
K_a = abutment contraction coefficient (*see* **4.4.2**);
H_e = head over crest, in m; and
W = total width of all piers, in m.

4.4.1 Recommended values of K_p are as follows:

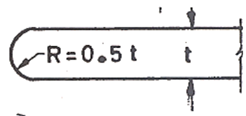
a) For square nose piers with corners rounded with radius equal to about 0.1 of the pier thickness:

$K_p = 0.02$



b) for rounded nose piers:

$K_p = 0.01$



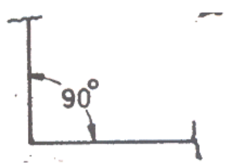
c) For pointed nose piers:

$K_p = 0.00$

4.4.2 Recommended values of K_a are as follows:

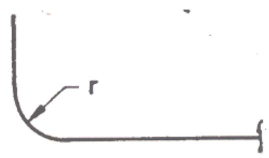
a) For square abutments with head walls at 90° to the direction of flow:

$K_a = 0.2$



b) For rounded abutments with head walls at 90° to the direction of flow for:

$0.5\,H_e \geq r \geq 0.15\,H_e$
$K_a = 0.1$



c) For rounded abutments where r > 0.5 H_e, and head wall is placed not more than 45° to the direction of flow:

$$K_a = 0$$

where

r = abutment rounding radius

4.5 Shape of Approaches and Other Component Parts

The shape of approaches and other component parts should preferably be fixed by means of model studies. However, for works of medium size the criteria given in **4.5.1** and **4.5.2** may be adopted.

4.5.1 At the upstream inlet a smooth entry should be ensured by providing circular, elliptical or hyperbolic transitions at shown in Fig. 1A and Fig. 2. The splay may be of the order of 1 : 1 to 3 : 1. These transitions should be confirmed by model studies, where necessary.

4.5.2 At the downstream side, straight, parabolic or hyperbolic transitions should be provided as shown in Fig. 1A and Fig. 2. The splay may be of the order of 3 : 1 to 5 : 1. These transitions should be confirmed by model studies, where necessary.

4.5.3 Wing walls should normally be kept vertical up to the end of the impervious floor beyond which they should be flared from vertical to the actual slope of the canal section. However, in order to obtain greater economy the wing walls may be kept vertical up to the toe of glacis and beyond this they may be flared gradually to 0.5 : 1.

4.6 Safety of Structure on Permeable Foundation from Surface Flow consideration

In the case of regulators on permeable foundation, the factors enumerated in **4.6.1** to **4.6.4** should be determined. In case of downstream non-erodible beds protective measures may not be necessary.

4.6.1 *Depth of Upstream Cut-off in Relation to Scour*

On the upstream side of the head regulator, cut-off should be provided and taken to the same depth as the cut-off stream of diversion work.

4.6.2 *Basin Dimensions and Appurtenances*

These should be provided in accordance with IS 4997.

4.6.3 *Thickness of Floor on Sloping Glacis with Reference to Hydraulic Jump*

The hydraulic jump profile should be plotted under different conditions of flow. Average height of the jump through should then be obtained by deducting the levels of the jump profile from corresponding hydraulic gradient line. This will be taken as the unbalanced head for which safety of glacis floor should be ensured. As a rough guide the unbalanced head may be assumed to be 1/2 ($d_2 - d_1$) where d_1 and d_2 are conjugate depths at the beginning and end of the hydraulic jump.

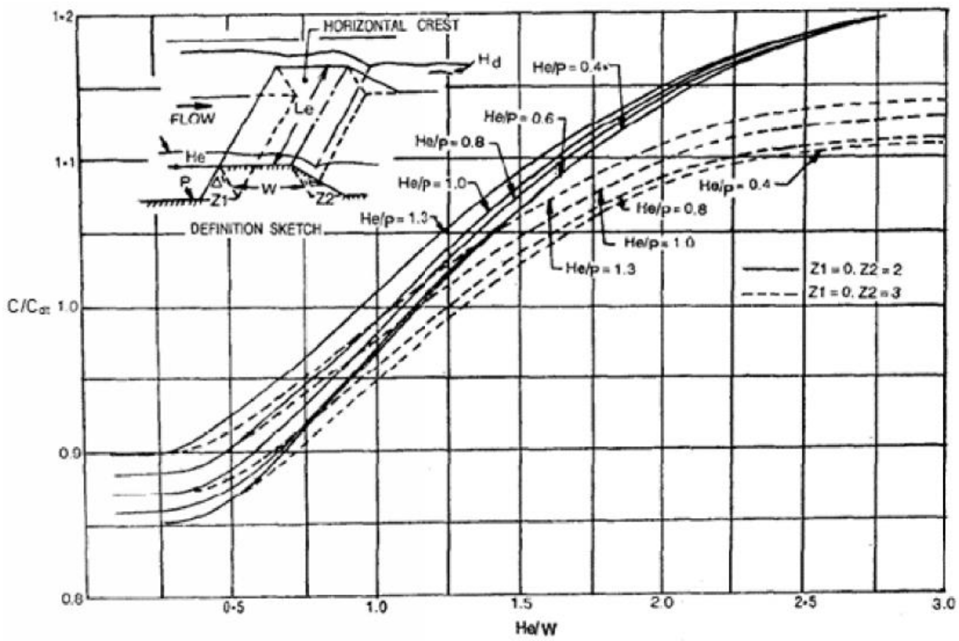
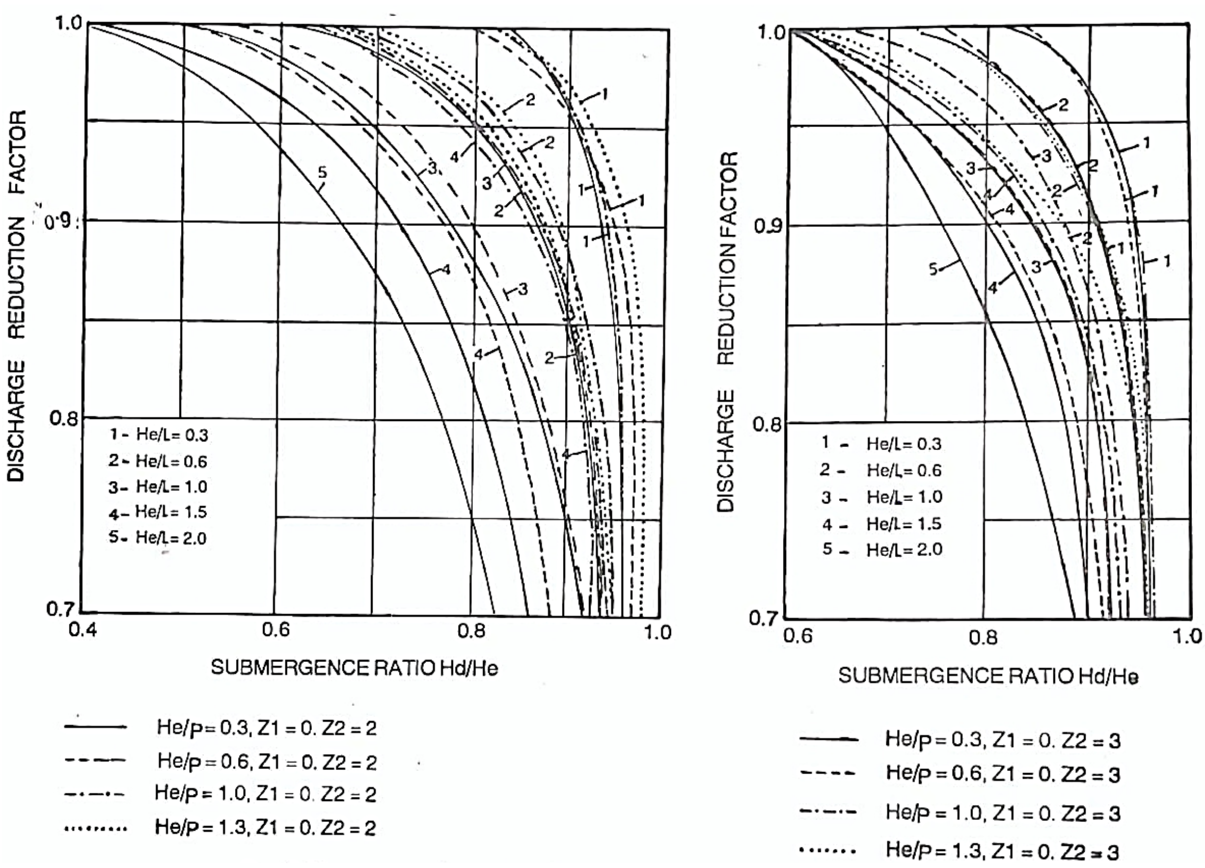


FIG. 4 RECOMMENDATION OF COEFFICIENT OF DISCHARGE FOR VARIED H_e P AND W



NOTE — Value of '*L*' can be determined by model test analysis.

FIG. 5 VARIATION OF DISCHARGE REDUCTION FACTOR FOR SUBMERGED FLOW

4.6.4 *Length and Thickness of Upstream and Downstream Loose Aprons*

Just at the end of concrete floor on the downstream an inverted filter 1.5 to 2 d long (d being the depth of scour below bed), consisting of 600 to 900 mm deep concrete blocks with open gaps (100-150 mm to be suitably filled with coarse material) laid over 500 to 800 mm graded filter, should be provided. The graded inverted filter should conform to the following design criteria:

$$\frac{D_{15}\text{ of filter}}{D_{15}\text{ of foundation}} \geq 5 \geq \frac{D_{15}\text{ of filter}}{D_{85}\text{ of foundation}}$$

where *D,* in mm

4.6.4.1 Downstream of the inverted filter, loose apron 1.5*D* long consisting of either boulders of not less than 40 kg in weight or wire boulder crates should be provided so as to ensure a minimum thickness of 1 m in launched position.

4.6.4.2 Upstream of the impervious floor, blocks and loose apron should be provided which should be similar to that provided in the corresponding weir or barrage.

4.7 Safety of Structure on Permeable Foundation from Sub-surface Flow Considerations

For this, the factors enumerated from **4.7.1** to **4.7.3** should be considered.

4.7.1 *Exit Gradient at the End of Impervious Floor*

It should be determined from accepted formulae and curves. The factors of safety of exit gradient for different types of soils should be as follows:

a) Shingle 4 to 5
b) Coarse sand 5 to 6
c) Fine sand 6 to 7

4.7.2 *Total Floor Length of Impervious Floor and Depth of Downstream Cut-off*

These two parameters are inter-related. Total floor length can be decreased by increasing the depth of downstream cut-off and vice versa, but increase in the depth of downstream cut-off should result in increase in the concentration of uplift pressures, especially in the lower half of the floor. A balance between the two should be arrived at on the basis of economic studies and other requirements, if any.

4.7.2.1 Minimum of total floor length required should be the sum of:

a) horizontal floor in the downstream from surface flow considerations (*see* **4.6**);
b) length required to accommodate sloping glacis and crest; and
c) about 3 m extra, upstream of the crest or length required from other considerations.

4.7.2.2 Depth of downstream cut-off should be worked out for this floor length to ensure safe exit gradient. If depth of downstream cut-off so calculated is excessive, it can be reduced in increasing upstream floor length. As a rough guide depth of downstream cut-off should not be less than ($d/2 + 0.5$), where d is the water depth in metre corresponding to full supply discharge.

4.7.3 *Thickness of Downstream Floor with Reference to Uplift Pressure*

Uplift pressures at key points on the floor should be determined from the accepted curves and formulae, corresponding to the condition of high flood level in the rivers upstream of head regulator and no water in the canal downstream of head regulator. Upstream of sill, only nominal floor thickness of about 1 m should be provided.

5 OPERATION

5.1 Provision for Breast Wall

If the maximum flood level to be attained after construction of the weir is not very high as compared to the full supply level of canal, that is, if the difference is up to 1 m, gates may be carried right above the high flood level. However, when the difference is considerable, economy may be achieved by limiting the height of gates and providing a breast wall to stop the floods.

5.2 Working Platform

A bridge and working platform should be provided for the operation of gates. The height of working platform depends upon the travel of gates. When there is a breast wall, the gate has to rise up to its bottom whereas in other case it has to go above high flood level. The working platform should be such that counter-weights are clear of water in the canal.

5.3 The canal head regulator may have to be operated under partially open conditions during high flood which may have to be taken under considerations while designing the height of gates.

6 SEDIMENT EXCLUSION DEVICES

6.1 Sediment excluder is a device constructed in the river bed in front of a canal head regulator to prevent, as far as possible, sediment entering into the off taking canal. Sediment exclusion becomes necessary, where excessive sediment entry into the canal causes silting-up and gradually reduces its capacity. Such devices are necessary, if sediment entering the canal is harmful.

6.2 Fundamental Principle

Stream carries most of sediment load of coarser grade near the bottom. If these bottom layers are intercepted and removed before the water enters the canal, most of the sediment load causing silting up would be withdrawn. This is generally achieved by constructing:

a) tunnel type sediment excluders suitably located in front of different bays of the head regulators, and
b) a curved channel with skimming weir towards the canal. It is recommended that hydraulic model tests be carried out to check the performance of the proposed design.

6.3 Design Criteria for Sediment Excluder

6.3.1 *Approach*

The river approach plays an important part and it should be kept straight to the mouth of the excluder tunnels as far as possible.

6.3.2 *Design of Tunnels*

a) *Location and Number of Tunnels* — The excluder tunnels are located in front of the canal head regulator and their alignment is generally kept parallel to the regulator. The number of tunnels is determined by the available discharge for escapages, approach conditions and length of the canal regulator. Usually four to six tunnels are provided. Any change in the alignment, if found necessary, should be on smooth curves.
b) *Spacing and Bell Mouthing of Tunnels* — The tunnel nearest to the head regulator has to be of the same length as that of the regulator. The consecutive tunnels should be spaced at such distances that the mouth of the one nearer to the head regulator comes within the suction zone of the succeeding tunnels and no dead zone is left between the two to permit sediment to deposit. The extent of suction and distance between mouth of two tunnels should normally be determined by model studies. Generally a distance of about 12 m may be adequate. The tunnels should be suitably bell mouthed at the inlet to minimize entry losses and improve suction. Bell mouthing should be done within the thickness of divide wall and may be done on any suitable elliptical curve.
c) *Size of Tunnels* — Size of tunnels depends upon the number of tunnels, self-clearing velocity of flow required to be provided, which may be kept 3 m/s for the alluvial and 4.0 to 4.5 m/s for the boulder stage river, and the discharge available for escapades. Besides, the convenience of a man for inspection and repairs should also be kept in view.

d) *Roof and Bed of Tunnels* — The roof slab of the tunnels should be kept flush with sill of the canal regulators and the bed kept at the upstream floor level of weir/anicut/barrage.

e) *Exit* — All the tunnels outfall into the stilling basin through one or two under sluice bays of the weir or anicut next to the canal regulator. It is usually one in case of sandy reaches and two in the case of rivers in shingle or boulder stage. The tunnels should be suitably throttled laterally or vertically or both as the conditions may be, to produce accelerating velocities in the tunnels, maximum being at the exit end so that sediment material once extracted does not deposit anywhere in the tunnels.

f) *Bend Radius* — Straight tunnels should be preferred for the sediment excluders, however, if a bend becomes inevitable, its radius may vary from 5 to 10 times the tunnel's width.

g) *Transitions* — All transitions to piers in bell mouthing at top or sides should preferably be elliptical, the major axis being in the direction of flow and two to three times the minor axis.

6.3.3 *Control Structure*

The excluder tunnels are operated by under-sluice gates. These should be regulated either for the tunnels to run full bore or to remain completely closed.

6.3.4 *Outfall Channels*

No separate outfall channel is required for the sediment excluders. As mentioned in **6.3.2** (e), these outfall into the river downstream of the weir or anicut through under-sluice bays. In the case of shingle or boulder bed rivers a provision of some additional contrivance that is, a sort of guide wall in the stilling basin may become necessary to eliminate formation of big deposits there.

6.3.5 *Escapage Discharge and Minimum Working Head*

Seepage discharge is generally governed by sediment size and load. Escapage discharge of 15 to 20 percent of canal discharge is generally required. A minimum of 0.5 m to 0.75 m working head is required for sediment excluders on sandy rivers and a minimum of 1.0 m to 1.25 m for excluders on shingle or boulder beds.

6.3.6 *Losses in Tunnels*

These should comprise friction losses and losses at the bends and transitions and should be computed by the following formulae:

a) Friction loss:

$$h_f = \frac{V^2 L N^2}{R^{4/3}}$$

where

h_f = head loss, in m;

V = Velocity in, m/s;

L = Length of tunnel, in m;

N = rugosity coefficient (*see* IS 10430); and

R = hydraulic mean depth.

b) Loss due to bend:

$$h_b = f\left(\frac{V^2}{2g}\right)\left(\frac{\theta}{180}\right) \text{ Where}$$

where

h_b = loss due to bend;

f = $0.124 + 3.134\,(S/2r)^{1/2}$;

g = acceleration due to gravity;

θ = angle of deviation, in degrees;

S = width of tunnel, in m; and

r = radius of bend along centre line of tunnel, in m.

c) Transitional loss due to change of velocity in expansion in metre.

$$h_e = K\left(\frac{V_1^2}{2g}\right) - \left(\frac{V_2^2}{2g}\right)$$

where

K = coefficient which may vary from 0.1 to 0.5 from gradual to abrupt transitions;

h_e = transitional loss due to change of velocity in expansion, in m;

V_1 and V_2 = velocities before and after the transition in, m/s; and

g = acceleration due to gravity in, m^2/s.

6.4 Design Criteria for Curved Channel Sediment Excluder for Spate Irrigation Head works

The layout of curved channel sediment excluder is shown in Fig. 3. Some factors relevant to such a design are:

a) River flow variability;

b) Sediment transport rates in the river;

c) Availability of water for sluicing purposes;

d) Availability of head for sluicing purposes; and

e) River mobility.

6.4.1 *Principle of Design*

Water surface in curved channel flow becomes super elevated (higher on the outside) and a spiral flow develops. The bottom current moves towards the inside of bend, and in this region the sediment will be moved away from the outside of the bend provided the current is sufficiently strong. For spate irrigation systems, the principle can be used by constructing a suitably curved local sluice and approach channel.

6.4.2 *Water Requirement for Sluice Flow*

A sluice flow of about 10 to 20 percent of the canal flow should be provided for sediment exclusion.

6.4.3 *Tail Water Level*

The efficiency of the curved channel sediment excluder is strongly dependent upon tail water level. For variation of tail water depths from 84 to 116 percent (of weir crest height from downstream floor) the efficiency varies from 75 to 30 percent. To preserve the curvature effect of the sluice channel velocities should not be too low and hence depths of flow should not be too large.

6.4.4 It is desirable to verify the hydraulic design of curved channel sediment excluder through model studies.

ANNEX A

(*Foreword*)

COMMITTEE COMPOSITION

Composition of Canal & Cross Drainage Works, Sectional Committee, WRD 13

Organization	*Representative(s)*
Central Water Commission, New Delhi	CHIEF ENGINEER DESIGN (N & W) (***Chairman***)
Brahmaputra Board, Guwahati	SHRI GAYA PRASAD SINGH SHRI SHYAMAL KR DEKA (*Alternate*)
Bhakra Beas Management Board, Punjab	DIRECTOR DESIGNS SUPERINTENDING ENGINEER (*Alternate*)
Central Board of Irrigation & Power, New Delhi	DR G. P. PATEL SHRI M. L. BAWEJA (*Alternate*)
Central Soil and Materials Research Station, New Delhi	SHRI RAJEEV KUMAR SHRI MAHABIR DIXIT (*Alternate*)
Central Water & Power Research Station, Pune	DR NEENA ISAAC SHRI SURESH KUMAR (*Alternate*)
Central Water Commission, New Delhi	DIRECTOR BCD (N & W) DIRECTOR (*Alternate*)
DHI (India) Water and Environment Pvt Ltd, New Delhi	DR FLEMMING JAKOBSEN
Indian Institute of Technology BHU, Varanasi	DR PRABHAT KR SINGH DIKSHIT
Jacob Consulting Engineering Services(India) Ltd, New Delhi	SHRI PIUSH K. DATTA SHRI RAJIB CHAKRABORTY (*Alternate*)
IIT, Roorkee, Roorkee	DR DEEPAK KASHYAP SHRI ASHISH PANDY (*Alternate*)
In Personal Capacity, Jaipur	SHRI Y. C. AGRAWAL
IIT, Delhi	DR B. R. CHAHAR
Irrigation Department, Govt of Andhra Pradesh, Hyderabad	SHRI I. S. N. RAJU SUPDT ENGINEER (CANAL) (*Alternate*)
Irrigation Department, Haryana	SHRI SANDEEP TANEJA SHRI PRADEEP YADAV (*Alternate*)
Irrigation Department, Govt of Punjab, Chandigarh	EXECUTIVE ENGINNER (CDO) DIRECTOR (CDO) (*Alternate*)
Irrigation Department, Govt of Uttar Pradesh, Lucknow	SHRI CHANDRA SHEKAR VISHWAKARMA SHRI UPENDRA NATH KUWAR (*Alternate*)
Irrigation Division, O/O Chief Engineer, Thiruvananthapuram	SHRI K. A. JOSHY SHRI MANJU BALAKRISHNAN (*Alternate*)
Irrigation Research Institute, Roorkee	SHRI LALIT KUMAR SHARMA SHRI NAVEEN SINGHAL (*Alternate*)
Maharashtra Engineering Research Institute, Nashik	SHRI RAJENDRA PAWAR SHRI M. M. PARATE (*Alternate*)
Narmada Water Resources, Water Supply & Kalpasar Deptt, Gandhinagar	SHRI A. M. BARVE SHRI B. H. CHAUDHARI (*Alternate*)
NHP Ltd, Faridabad	SHRI AJAY MITTAL SHRI SHRISH DUBEY (*Alternate*)

Organization	*Representative(s)*
Public Works Department Govt of Tamil Nadu, Chennai	SUPDT ENGINEER DESIGN, WRD SUPDT ENGINEER (CANALS) (*Alternate*)
Sardar Sarovar Narmada Nigam Ltd, Gujarat	DIRECTOR (CANALS) CHIEF ENGINEER (DESIGN) (*Alternate*)
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Water Resources Department Govt of Bihar, Patna	SUPERINTENDING ENGINEER
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